How Dry Should Concrete Decks Be...

For Application Of Liquid-applied Waterproofing Membranes?

By Kami Farahmandpour

INTRODUCTION

Over the past several years, a number of failures of liquid-applied waterproofing membranes (LAMs) have been documented. For the most part, these membranes had been installed directly over structural concrete decks.

One of the important issues in understanding the failure mechanisms in LAMs is that their performance is highly dependent on the integrity of the concrete substrate and their bond to the concrete. Deficiencies in the concrete substrate such as live (moving) cracks can easily reflect through the membrane and cause its failure.

One of the most prevalent modes of failure for such membranes is blistering and debonding of the membrane from the substrate. Since most LAMs are relatively thin (compared to sheet membranes) and do not have a reinforcing scrim incorporated into the assembly, local debonding can quickly cause failures in the membrane and water leakage.

Debonding of LAMs from concrete substrates is typically attributed to surface contamination and/or moisture emission from the concrete substrate. Of these two potential causes, moisture emission issues appear to be the most common mode of early failure of liquid-applied membranes.

Moisture Emission From Concrete Surfaces

Concrete is a porous material. The porosity of concrete greatly depends on its quality and water-to-cement ratio (w/c). As such, concrete always contains some moisture, in the same way that insulation boards have an equilibrium moisture value. Depending on the relative humidity and temperature of the concrete and relative humidity and temperature of the ambient air, concrete either emits or absorbs moisture in vapor form. This phenomenon is most often referred to as "breathing." Concrete can also absorb significant amounts of water.

In most cases, concrete surfaces that appear to be dry are either emitting or absorbing water vapor. If liquid water moves through the concrete, as long as the rate of evaporation from the surface is greater than the rate of moisture emission, the concrete surface appears dry. If moisture moves through the concrete in vapor form, the concrete surface will not have a wet appearance regardless of the evaporation rate.

When a liquid-applied membrane is applied to the surface of concrete, it creates a vapor retarder at the concrete surface that prevents moisture emission. Therefore, water vapor moving to the surface of the membrane cannot

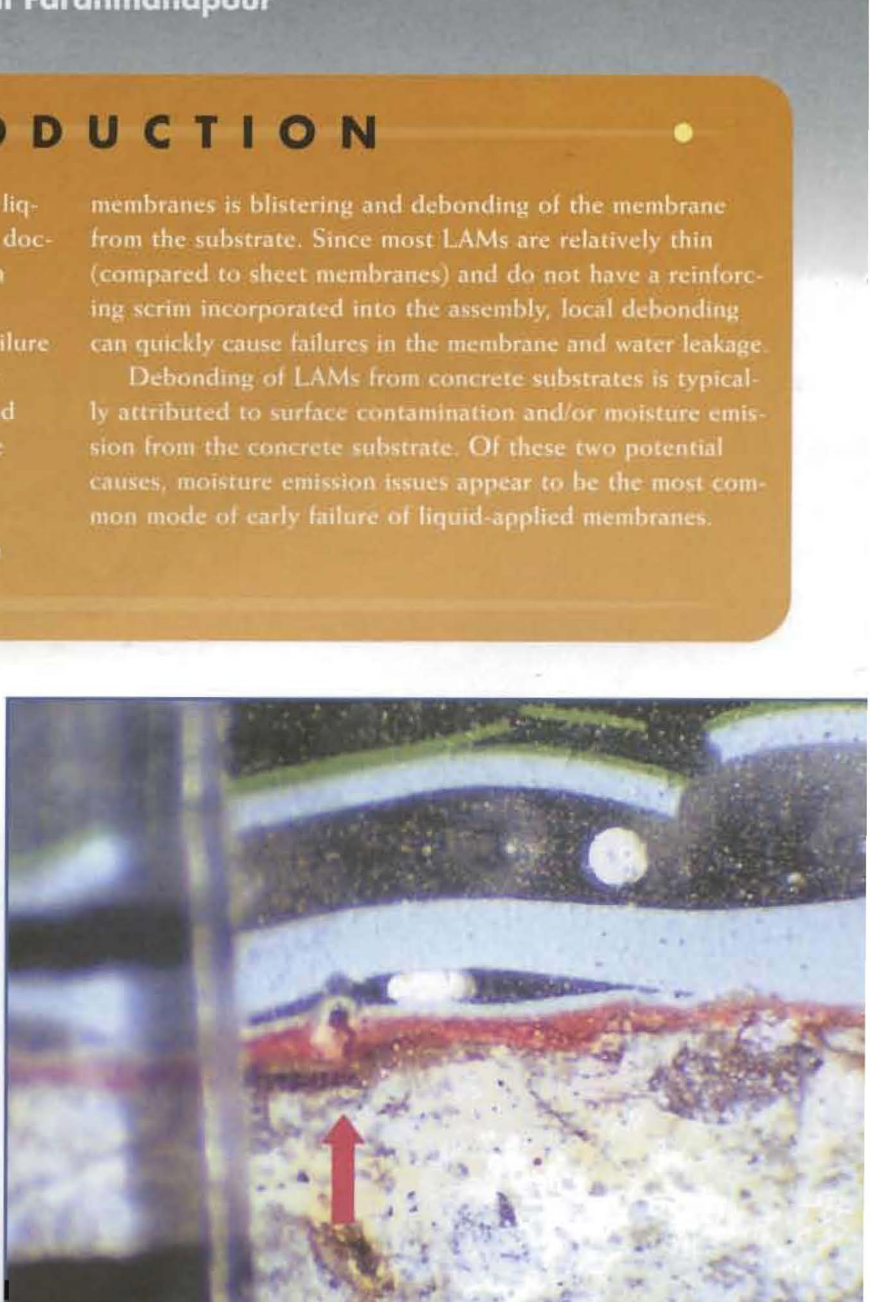

Figure 1 – Photomicrograph of a liquid-applied membrane over concrete. The red layer is an epoxy primer, the gray and green layers are base coat and top coat, respectively. Note the evidence of water vapor passage through the concrete surface (red arrow) and the resulting small blister above it.

escape, thus causing accumulation of water vapor pressure between the membrane and concrete surface. This phenomenon can occur within minutes of applying a LAM to concrete surfaces. Since most LAMs are chemically cured and require several hours to cure and establish bond to the substrate, build-up of water vapor pressure shortly after application can inhibit development of a proper bond between the membrane and the concrete substrate. Zones of weakened bond can manifest quickly as blisters filled with water and ultimately cause failure of the membrane (*Figures 1* and 2).

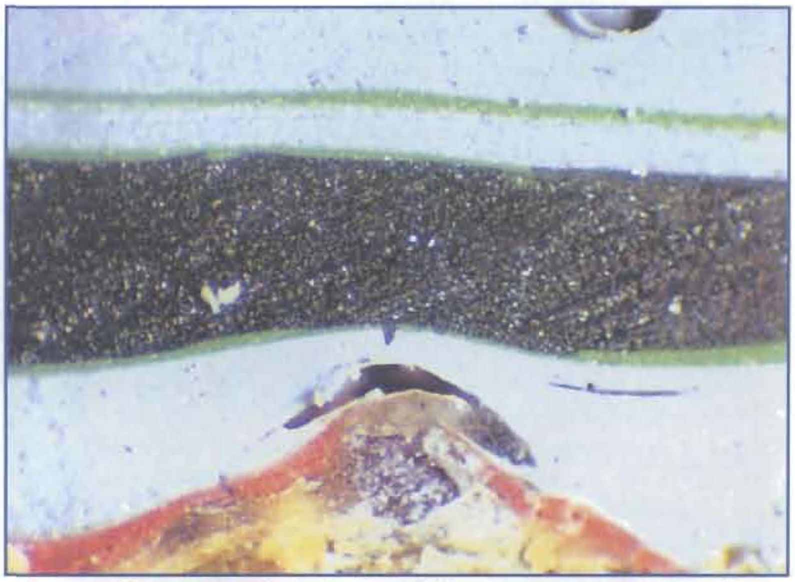

Figure 2 – Photomicrograph of a liquid-applied membrane on concrete. A small peak on the surface caused a discontinuity in the red epoxy layer allowing more moisture vapor to debond the membrane over it.

In some cases, the moisture being emitted from the concrete surface works its way to the outer surface of the membrane before the membrane cures. This typically manifests as pinholes in the membrane that can lead to leakage under hydrostatic pressure. However, it is important to note that other causes of pinhole formation do exist, such as entrained air due to application and formation of gases due to the membrane's chemical curing mechanism.

The Current State of the Industry

Despite the extent of problems associated with concrete substrate moisture emissions, there seems to be a lack of understanding in the industry regarding the required moisture conditions of concrete substrates prior to application of LAMs. There are also some myths regarding the causes of failure. For example, some believe that moisture vapor emission long after the membrane has cured can cause debonding and failure. With the exception of those few LAMs that are susceptible to alkali attack at the bond surface, such a mechanism cannot cause debonding of the membrane after it has cured and established proper bond to the substrate. The bond value of most membranes to concrete is in excess of 200 PSI, while the water vapor pressure differences are less than 1 PSI. As such, water vapor pressure alone cannot cause a physical failure at the bond line between a well-bonded membrane and the concrete substrate.

Figure 3 - ASTM F-1869 test being performed on a concrete floor.

Another common myth in the industry is that if the concrete is cured for 28 days, it will be suitable for application of liquid-applied membranes. Several membrane manufacturer application instructions indicate "fully-cured" or "28-day cured concrete" as the only moisture criteria for application of their membrane. The most important factor to consider is service environment. If the concrete has cured for 27 days and then is exposed to rain, the moisture content in the concrete will be increased to a level close to the initial moisture content and will require a longer drying time than concrete that is kept continuously dry. Other factors such as ambient temperature and humidity during curing will affect the rate of drying. The age of concrete does not correlate well with its moisture vapor emission rate (MVER).

Other manufacturers stipulate that the concrete "shall be dry" prior to application of their material. If "dry" implies completely free of moisture, in the author's opinion, obtaining "dry" concrete in most construction projects is impractical. The term "dry" needs to be clearly defined by the manufacturer, and specific acceptance criteria should be provided.

Some in the industry have tried to establish a concrete substrate moisture criterium that is related to the concrete moisture content. The draft version of ASTM C-898 (1) recently circulated to ASTM Committee C-24 members stipulated a maximum substrate concrete moisture content of 8% as a requirement for application of LAMs. Direct measurement of concrete moisture content is impractical in most cases. Furthermore, good correlation between concrete moisture content and its MVER does not exist.

Prior to application of bonded flooring systems, the flooring industry typically specifies ASTM F-1869 (2) to measure the amount of moisture vapor emitted from concrete. This test takes approximately 72 hours to complete, and results are expressed in pounds of moisture vapor emitted through the surface in 24 hours for 1000 square feet of concrete surface (*Figure 3*). The test is currently being reviewed by an ASTM committee to address some precision and bias issues. The results obtained reflect only the condition of the concrete at the time of the test. Despite its drawbacks, in the author's opinion, this test method is a good tool for evaluating the MVER of concrete surfaces.

Currently, no industry standard exists for threshold MVER values obtained through ASTM F-1869 prior to application of LAMs. However, a value of 3.0 pounds in 24 hours/1000 sf has been used by some as the threshold for application of impermeable membranes.

While concrete MVER can be remotely related to its moisture content, other factors such as ambient relative humidity and temperature and concrete temperature play a large role in determining MVERs from concrete surfaces.

Other methods, such as measuring the relative humidity gradients within the concrete slabs, have been used by Europeans with success. This method involves drilling holes in the concrete, placing relative humidity probes at different depths, and monitoring drying of the concrete over time. Experienced operators are required to gather and interpret the data. These methods are currently somewhat sophisticated for everyday use at construction sites and have not gained widespread acceptance in the United States.

Recommendations

Further research is needed to better understand the mechanisms involved in moisture-related failure of LAMs. Manufacturers of each product need to clearly specify acceptance criteria relating to the moisture condition of the concrete substrate. This would involve the type of testing and interpretation of the data. The author recommends that manufacturers of LAMs evaluate their installation instructions and incorporate meaningful and measurable criteria for acceptability of substrate conditions.

Although methods to evaluate MVER from concrete surfaces are available, manufacturers of each membrane should establish acceptable thresholds for MVER. ASTM F-1869 is a tool that can indicate potential moisture-related problems. Since the curing time of LAMs varies greatly, the impact of MVER on bond development will be different for various products and should be evaluated for each product separately.

Manufacturers of LAMs and specifiers should be aware of the impact of MVER on membrane bond development. For example, application of a LAM on a concrete surface in late afternoon typically results in a higher MVER. This is due to the higher temperature of concrete as a result of solar gain. The higher temperature of concrete increases the vapor pressure within the concrete and results in a higher MVER. Conversely, application of a membrane on a concrete deck in morning hours may result in a lower MVER since the concrete may be cooler than the ambient temperature in morning hours. ■

REFERENCES

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2. American Society for Testing and Materials, ASTM F-1869, "Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride."

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